Design and Software Development of Automated Data Acquisition System for Load Cell Calibration

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ABSTRACT

The data acquisition system for loadcell calibration has been upgraded from a dedicated instrument controller to a desktop computer with a Microsoft® WIN95 operating system. This paper includes a discussion of the selection of the instrumentation, software, design of the switching network, and software development. The system is controlled and monitored by software developed using National Instruments graphical programming language, LabVIEW. Data reports are generated in Microsoft Excel using Object Linking and Embedding (OLE) routines from LabVIEW. Data are archived in Microsoft Access with OLE routines from LabVIEW. Reports and historical data are electronically available to the test facilities at Arnold Engineering Development Center (AEDC) over the base Intranet.

INTRODUCTION

The data acquisition for loadcell calibration at AEDC had been performed using a HP 3497A data acquisition/control unit with HP 87XM computer and application programs developed in HP Basic software. The data acquired were stored on a floppy disk and transferred to a DEC VAX 11/785 for data reporting and storage of summary history into indexed files.

The objectives for the upgrade of this system are to improve the accuracy of the data acquired, eliminate the manual transfer of data for report generation and archiving, and to provide paperless and automatic transfer capability of reports and historical information to the AEDC test facilities. A system has been designed and implemented to meet these objectives.

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* The research reported herein was performed by the Arnold Engineering Development Center (AEDC), Air Force Materiel Command. Work and analysis for this research were performed by personnel of ACS, support services contractor for AEDC. Further reproduction is authorized to satisfy needs of the U. S. Government.

SYSTEM DESCRIPTION

The major components in this system include a HP 3458A DMM, a HP 3488A switch/control unit, a Gateway P5-166 PC, and a Power Designs 5020 DC power supply (Fig. 1).

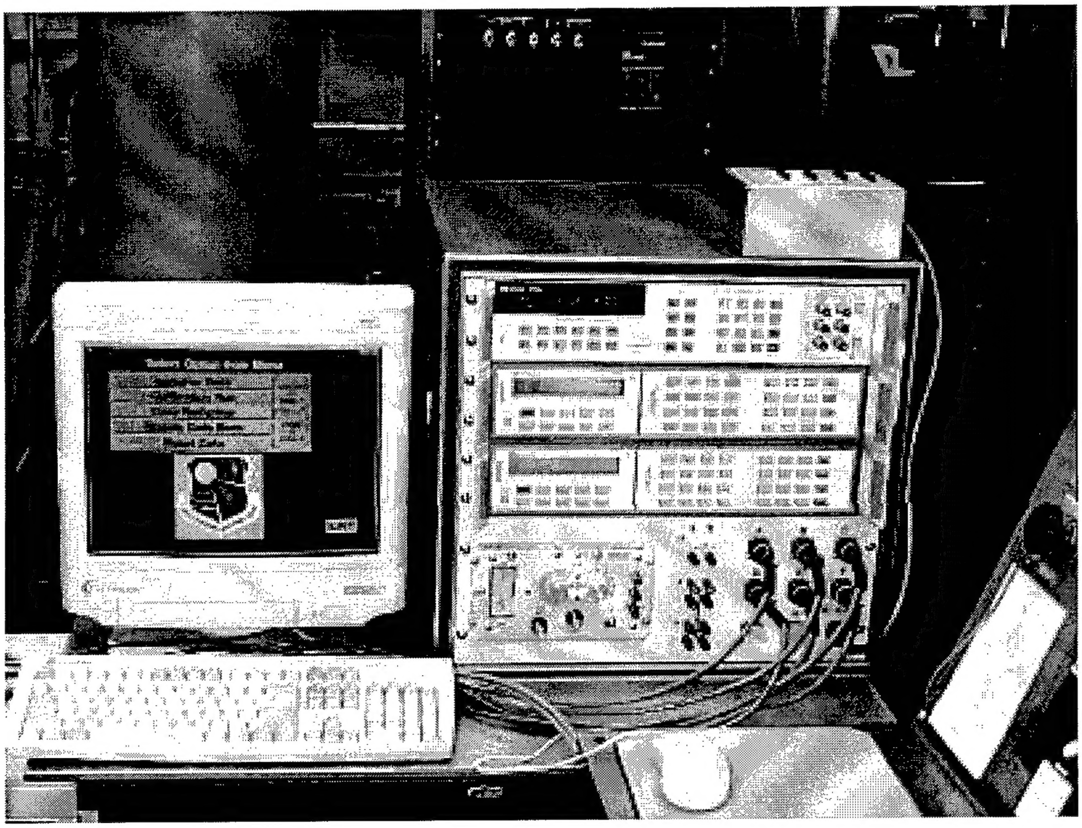

Figure 1. System Components

The HP 3458A Digital Multimeter (DMM) provides an increase in resolution of the loadcell bridge output from 1 μV to 0.01 μV and an increase in accuracy of ± (9 ppm of reading + 0.3 μV) versus ± (70 ppm of reading + 3 μV). The HP 3458A not only improved the accuracy of the measured output signal, but also allowed the operator to more accurately determine when a loadcell had stabilized after application of a dead weight due to the increased resolution of the DMM. The HP 3488A switch/control unit is used to switch up to eight-bridge outputs to the DMM for measurement. In the design of the switching network, a desired capability was added to monitor the excitation at the loadcell connector for each bridge and provide the capability to reverse the excitation voltage to minimize thermal voltages developed in the system and loadcell. The switching network also allows for measurements of the loadcell bridge's input and output resistance, and automatic application of shunt resistors around each bridge for simulated force checks.

The control software for this system uses National Instruments LabVIEW graphical programming language, G. This graphical language was selected over other text programming languages such as Microsoft Visual C and Basic for its ease of use and extensive instrumentation libraries. Although LabVIEW is the language for the controlling program, the system takes advantage of other

Microsoft Office 97 products for data reporting and archiving. Figure 2 illustrates a typical report. The system uses OLE to transfer data from LabVIEW to Excel for data reduction and reporting. Visual Basic modules inside the Microsoft Excel workbook are used for functions to calculate Maximum Non-Linearity, Hysteresis, Non-Repeatability, and equivalent forces for resistance calibration. The final results and descriptive loadcell information are stored in Microsoft Access database tables.

Arnold Engineering Development Center
Precision Measurement Equipment Laboratory
Calibration Report

Transducer, Force
Identification Number: Z048056 Bridge A
Manufacture: Toroid Corp.
Range: ±50,000 lbf
Model Number: 35U-223-1A
Serial Number: 57866

Calibration Date: 03/19/1998
Calib. Procedure: COMM DATA

Mating Connector: MS3116F-12-10S
Positive Input Connections : A and F
Negative Input Connections : D and J
Positive Output Connections: B and G
Negative Output Connections: C and H
Shield Connections : E and K

Excitation : 10.000 Volts DC
Temperature: 73.0 Deg F

Resistance Values

Input Resistance: 351.3 Ohms
Output Resistance: 352.3 Ohms
Isolation Resist : 10.0 Gigaohms

Current Summary

	Compression	Tension
Calibrated Range LBF :	30,001	30,001
Zero Unbalanced MV/V :	0.0296	0.0296
C.R. Sensitivity MV/V :	-1.7991	1.8004
Max. Non-Linear %C.R.:	-0.0297	-0.0292
Max. Hysteresis %C.R.:	-0.0433	0.0301
Max. Non-Repeat %C.R.:	0.0038	0.0015

Previous Summary

	Compression	Tension
Calibration Date :	12/01/1997	
Calibrated Range LBF :	30,001	30,001
Zero Unbalanced MV/V :	0.0289	0.0289
C.R. Sensitivity MV/V :	-1.7993	1.8003
Max. Non-Linear %C.R.:	-0.0283	-0.0315
Max. Hysteresis %C.R.:	-0.0438	0.0315
Max. Non-Repeat %C.R.:	0.0021	0.0019

Terminal Linearity

Force LBF	Compression MV/V	Tension MV/V
0	0.0296	0.0296
6,000	-0.3299	0.3892
12,000	-0.6895	0.7492
20,001	-1.1694	1.2296
25,001	-1.4695	1.5298
30,001	-1.7696	1.8300
25,001	-1.4698	1.5302
20,001	-1.1700	1.2301
12,000	-0.6903	0.7497
6,000	-0.3304	0.3895
0	0.0296	0.0295

Calibration Equipment

Id no.	Instrument	Calib. Date
Z004926	DW machine, Cox	05/27/1964
Z004946	Megger, Keithley	04/18/1997
Z068824	DMM, HP 3458A	08/04/1997

Resistance Calibration

R-Cal ID: SN2225 Type: DS SINGLE Shunt

R-CAL Steps/Pins	Nominal K-Ohms	Output MV/V	Equivalent Force LBF
COMP-1 F&H	100.000	-0.8479	14,633.97
COMP-2 F&H	50.000	-1.7212	29,194.79
COMP-3 F&H	33.333	-2.5920	43,712.16*
COMP-4 F&H	25.000	-3.4590	58,166.08*
TENS-1 F&G	100.000	0.9063	14,612.27
TENS-2 F&G	50.000	1.7789	29,150.03
TENS-3 F&G	33.333	2.6490	43,650.48*
TENS-4 F&G	25.000	3.5153	58,087.40*

*Linear Extrapolation

Notes

CAL'D TO 30KLBF W/ FTNGS TQD 100FTLBS.
CAL'D W/(A)SN2225 (B)SN4884 CARDS.

Calibrated by

Figure 2. Typical Calibration Report

The PC for this system is connected to the AEDC base Intranet. Information is available to the test facilities immediately upon completion of a calibration to update their database instrument books for determining thrust of rocket motors and aircraft engines being tested.

SOFTWARE DEVELOPMENT

The G programming language was used extensively in the software development of the application program. The G programming environment uses Virtual Instruments (VI's) as building blocks for programs. These can be thought of as subprograms in a Basic language. The VI's contain a front panel that the Windows environment can display or hide when executed, and a block diagram, the source code for the VI. This application program is broken up into over 100 VI's that allow simpler building blocks to be reused throughout the structure of this program, and in the development of future programs. An example of a G program block diagram is shown in Fig. 3. In this example there is an outer While Loop that the program remains in until an Exit button is depressed on the front panel. When the option button is depressed a Case Structure is selected. Inside the displayed Case 5 is a Sequence Structure with 0 through 7 steps. The displayed Sequence 0 has two VI's inside it, WB Open, to open an Excel workbook, and WS Open, to select a worksheet, named Data, inside the workbook. Global variables are used to pass the spreadsheet file name, error clusters, and reference numbers required by subsequent OLE communications with the workbook.

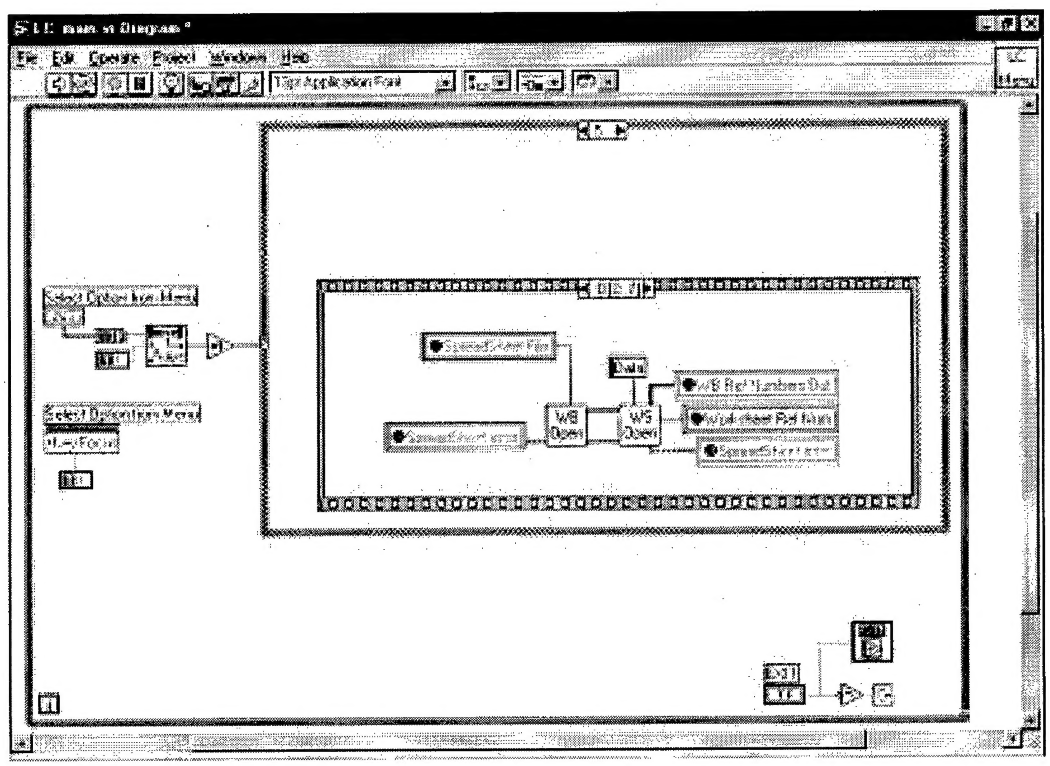

Figure 3. Typical LabVIEW VI

The application program takes advantage of VI's distributed by National Instruments for controlling and monitoring the HP 3458 DMM and HP 3488 switch/control unit.

A major undertaking was the development of the VI's required for OLE communications. An example of this is the WB Open in Fig. 3. This VI is written to allow an EXCEL workbook to be opened for subsequent EXCEL methods or properties to be performed. Figure 4 shows the front panel for the WB Open, and Fig. 5 shows its block diagram. This VI opens an Excel application and creates reference numbers, Excel Application, Workbooks Collection, and Workbook to be used by subsequent property or method commands. The Excel application can be made visible, or, by default, left in the background. Next, optional parameters, such as workbook password, are passed into Excel when the workbook is opened with the EXEC Method VI. VI's were developed to execute all the properties or methods required for the Excel and Access communications used in the application program. An obstacle in this work was finding the method or property to execute a desired function such as Clear Cell Contents in an Excel worksheet. This required use of the HELP files in the Excel and Access applications. LabVIEW 5.0 version made this process much easier with the development of ActiveX technology that loads in the available methods or properties for any application that conforms to this technology and taps into the on-line help for the method or property directly from LabVIEW.

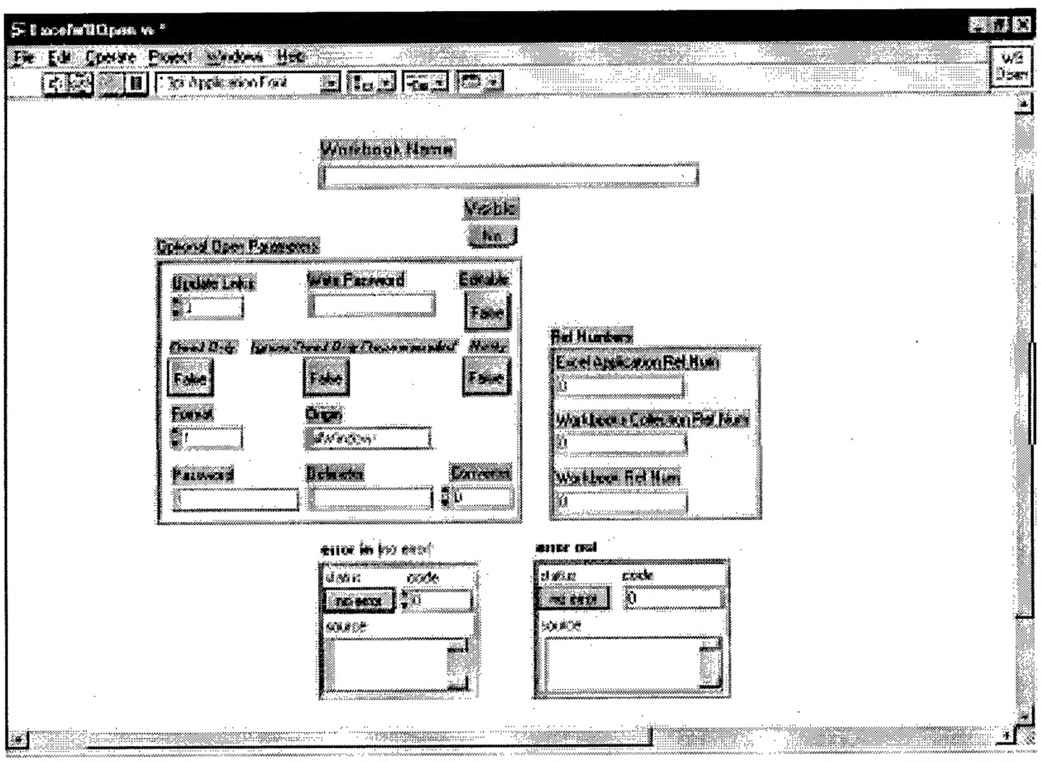

Figure 4. WB Open Front Panel

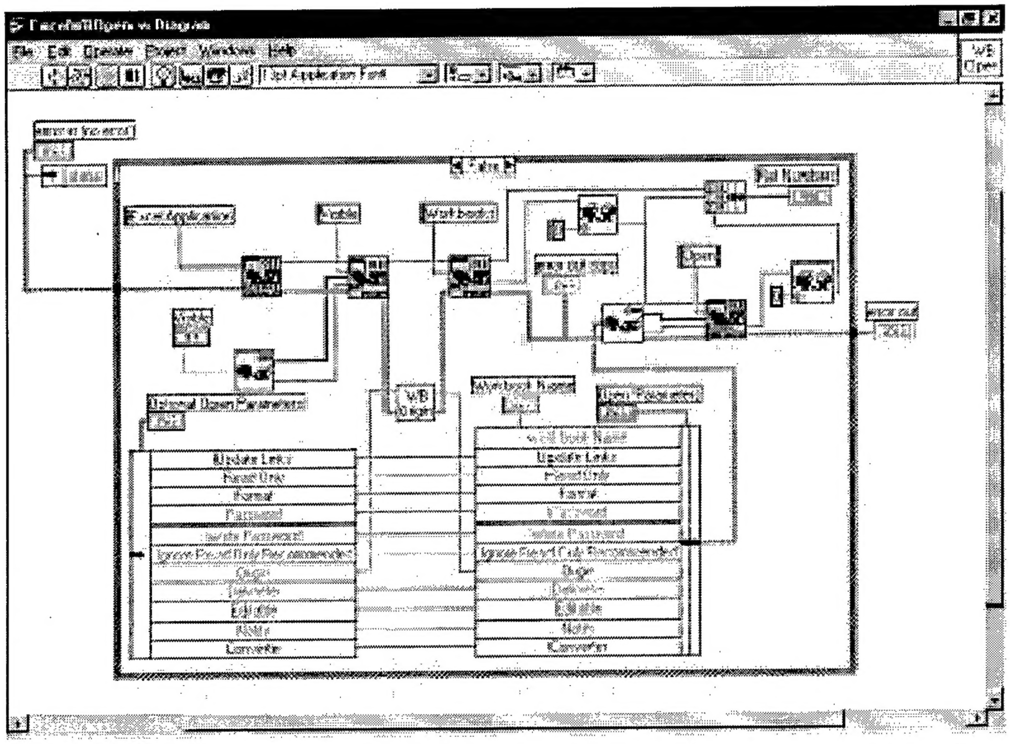

Figure 5. WB Open Block Diagram

Figure 6 illustrates a more detailed block diagram of a VI. The Sequence shown is using OLE routines to read data from an Excel spreadsheet and write this information into a G Cluster.

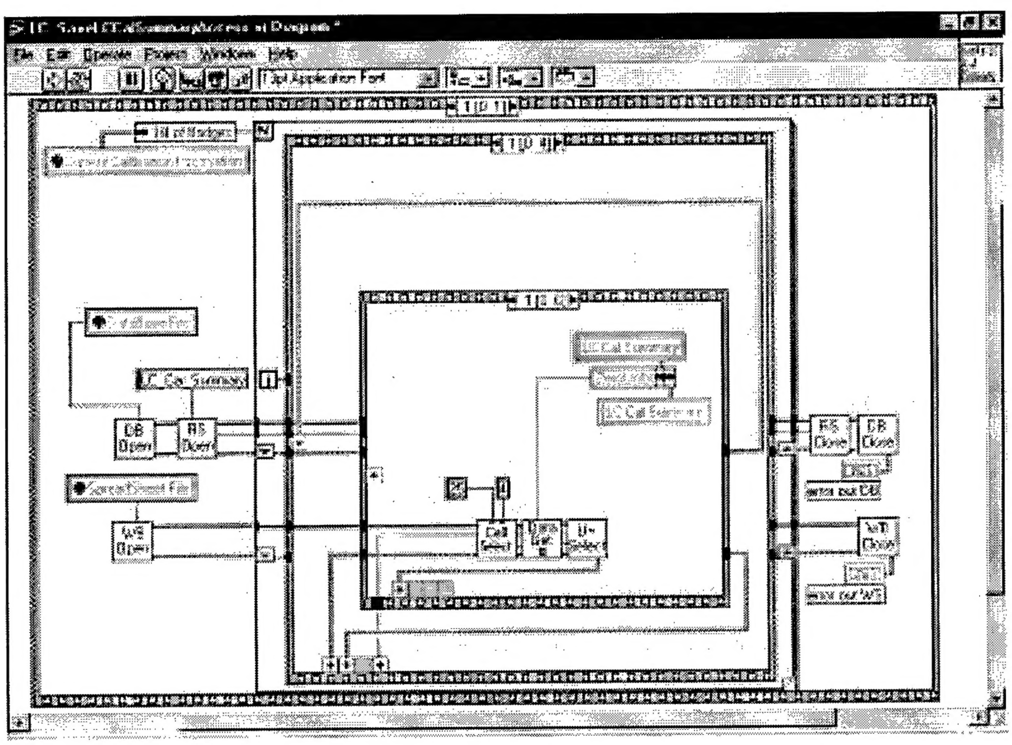

Figure 6. Block Diagram of Reading Excel Data and Writing Data to Access

The complete Sequence obtains all of the information from the Excel worksheet and the final step in the Sequence writes this information as a record to an Access table.

SYSTEM OPERATION

The Main Menu for operation of this system is depicted in Fig. 7. The normal sequence is for the operator to select Initialize Data. This selection initializes the data in the Excel workbook and prompts the operator to enter the identification number for the loadcell being calibrated. If the loadcell has been calibrated previously by this system, the fixed file information (such as number of bridges, range, serial number, etc.) is retrieved using OLE from the Access database; otherwise, the operator enters this information and it is stored into the database. The operator also has the opportunity to modify any errors in the instrument fixed file information at this time. If the loadcell has been run on this system previously, summary information (such as calibration date, calibrated range sensitivity, zero unbalance, maximum non-linearity, hysteresis, and non-repeatability) is automatically written from the database to the workbook. Otherwise, the operator is allowed to enter the summary information, if any, for each bridge from the most recent calibration. The system then returns to the Main Menu.

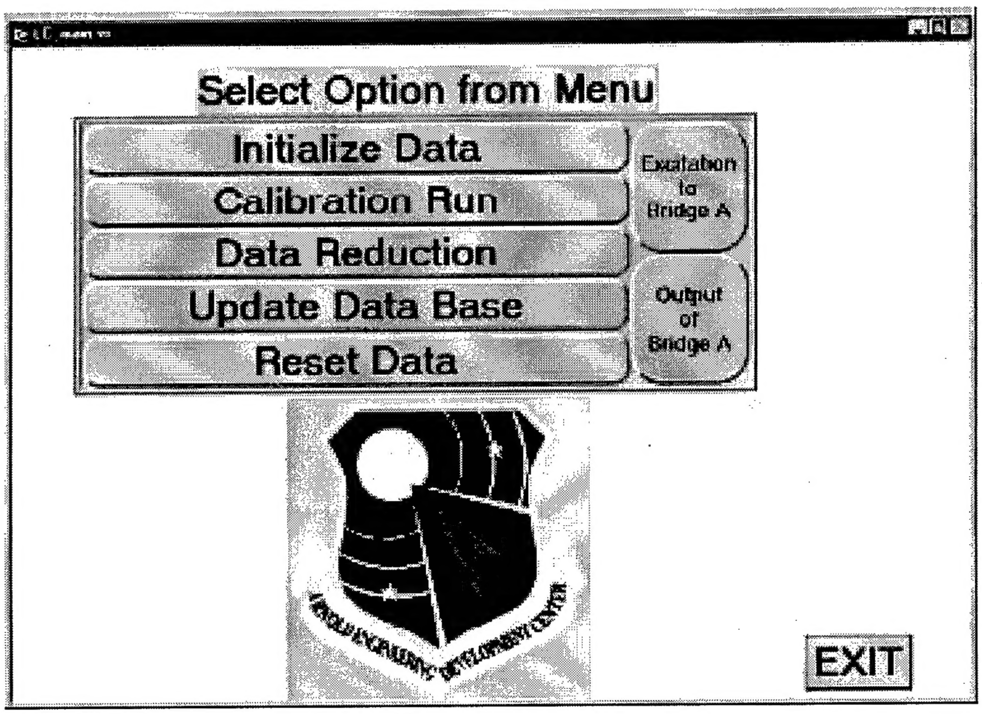

Figure 7. Main Menu

Next, the operator selects Calibration Run, followed by another menu to select Resistance, Compression, Tension, or R-Cal calibration. The Resistance calibration measures each bridge's input and output resistance and allows the operator to enter isolation resistance for the loadcell. The Compression and Tension calibrations test the repeatability and linearity for each bridge mounted for compression or tension loading. Figure 8 is an example of the screen displayed during a Compression calibration for a six-bridge loadcell. The upper portion of the screen shows the voltage readings of the bridge currently being read by the system. The excitation at each

bridge is read before each mV output measurement; the mV/V ratio is shown for each measurement. The excitation is reversed and the process is repeated. The reported mV/V output at each test point is the average of the positive and negative excitation. The data for each bridge are then written into the appropriate arrays for the completed test point. The operator is then prompted to accept or repeat the measurement of this data point. This example is testing the loadcell with three repeatability steps from 0 to full scale, then an 11-point linearity test, starting at 0, ascending nominally 20-percent steps to full scale, then descending at the 20-percent steps to 0 force. The ascending data points are used to calculate the maximum non-linearity in the bridge, and the difference between the ascending and descending data points is used to calculate the maximum hysteresis in the bridge. The R-Cal calibration automatically applies shunt resistors at selected legs of the bridge and then measures the bridge output. The output is used to compute an equivalent force based on the bridge output during the linearity run. The R-Cal outputs are used by the test facilities as in-place verification, and to set up their signal conditioning instrumentation for thrust measurements. When all required calibration tests are complete, the operator exits the Calibration Run menu and returns to the Main Menu.

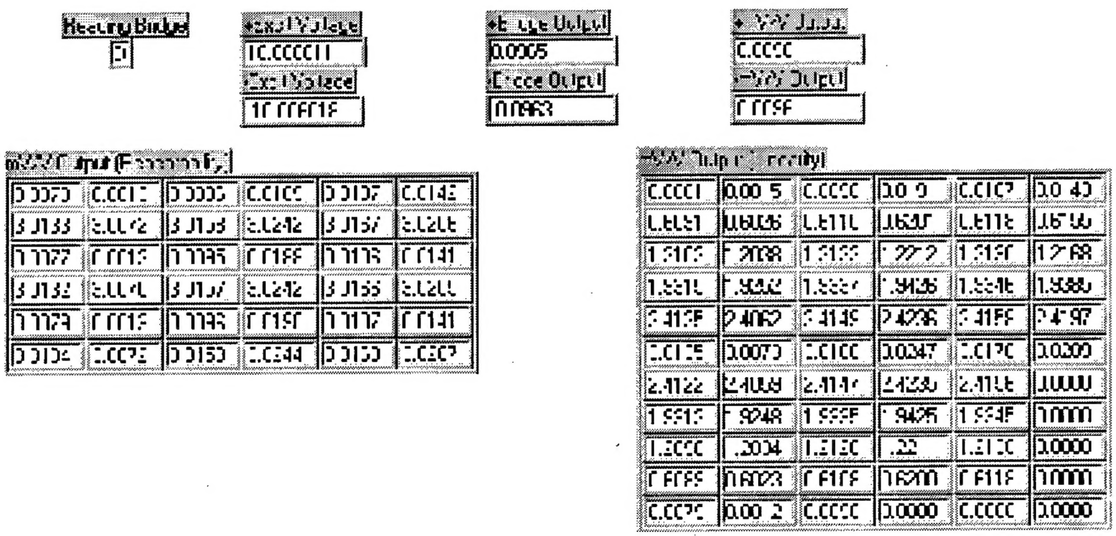

Figure 8. Compression Calibration Display

Normally, the next sequence is to select Data Reduction from the Main Menu. This selection opens the Excel workbook, performs calculations on the data that are stored in the workbook from the Calibration Run, and prints a report to a laser printer connected to the AEDC base Intranet. The program then returns to the Main Menu.

The operator examines the data, notes any measurements outside specifications for the loadcell, and determines if there were any errors in the calibration. If data points are suspect, a specific calibration test can be re-run. After determining that the calibration report is acceptable, the operator selects Update Data Base. The information from the calibration report is then written to the tables in the Access database for a permanent record.

The Reset Data option is mainly used if the program is interrupted prior to completing calibration of a loadcell. It resets the LabVIEW global variables, but does not initialize the Excel workbook of previously stored data for the loadcell being tested. This option is also used for multiple R-Cal type calibrations performed on a loadcell.

FUTURE ENHANCEMENTS

There are several future enhancements anticipated for the system which include:

1. Creating a form inside the Access database to provide a menu-driven selection of a calibration report for a specific loadcell and calibration date.

2. Developing specification tables in Access to automatically determine when loadcell calibration results are outside limits and note the out-of-tolerance conditions on the report.

3. Moving the Access data to Oracle for enhanced database capabilities.

4. Adding the capability to measure the output from a standard loadcell and calculate the force being applied to the standard and test loadcell in the hydraulic calibration stand.

5. Upgrading the loadcell application program to the recently released LabVIEW 5.0 version to take advantage of ActiveX capability of OLE communication.

6. Investigating the feasibility of automating the process of applying the dead weights in the 133.45 kN (30 klbf) and the force in the 222.4 kN (50 klbf) hydraulic stand.

CONCLUSIONS

A system has been developed and implemented to meet the desired objectives of the data acquisition system upgrade. The system is Windows-driven, user friendly, and takes advantage of commercial off-the-shelf programs for gathering, reporting, and archiving data.

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